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# Wireless Propagation Research

## Outputs

- Survey and implementation of data analysis and modeling techniques for multipath channel estimation.
- Methods for the prediction and measurement of wireless indoor radio channel characteristics.
- Assessment of geometric optics approximation for indoor ray-trace models.

The Institute has been involved in research efforts related to wireless communication applications and theory. More specifically, ITS develops models and measurement systems to estimate propagation characteristics of various multipath environments. The objectives of these efforts are to support new wireless technology development and help U.S. industry compete in the worldwide telecommunications marketplace. In the past, a majority of the wireless research has been related to the outdoor propagation environment. Recently, with the emergence of new indoor wireless local area networks and wireless local campus networks, the research has been extended to indoor scenarios.

ITS is able to measure and model the transfer function of a wide variety of wireless radio links. The data is non-deterministic and there is significant complexity in reducing that data into a concise set of metrics with limited ambiguity. Signal attenuation is a performance metric that can be expressed statistically and straightforwardly. However, time-dispersion parameters that reflect the bandwidth limitation imposed by the channel are not so clear cut. Historically, researchers have used RMS (root mean square) delay spread as a dispersion metric because of the derived correlation with bit error ratio (BER) for channels with Gaussian, wide-sense stationary, uncorrelated-scattering characteristics. There are a number of adverse wireless radio environments, however, where the frequency-domain statistics

are dynamic over small distances and the justification for using rms delay spread is compromised.

Over the course of the last year an extensive literature search was conducted on characterization for wireless channels. The resulting article database provided numerous processing and modeling techniques for consideration. Those procedures were incorporated into a channel characterization toolbox for MATLAB, which has proved to be a useful tool for system evaluation, data comparison, statistical analyses, model development, presentation of results, and distribution of data.

In an attempt to understand antenna polarization and directivity effects indoors, impulse response measurements were acquired in a number of scenarios (e.g., in-room, in-corridor, obstructed line-of-site) employing different types of antennas. An effective method of presentation for this data is shown in Figure 1. The left plot shows time dispersion versus excess loss; this provides a clear comparison between different channels and demonstrates a correlation between the two metrics. The right plot is the cumulative distribution function of maximum delay on Gaussian paper, which provides an intuitive view of the distribution for that random variable.

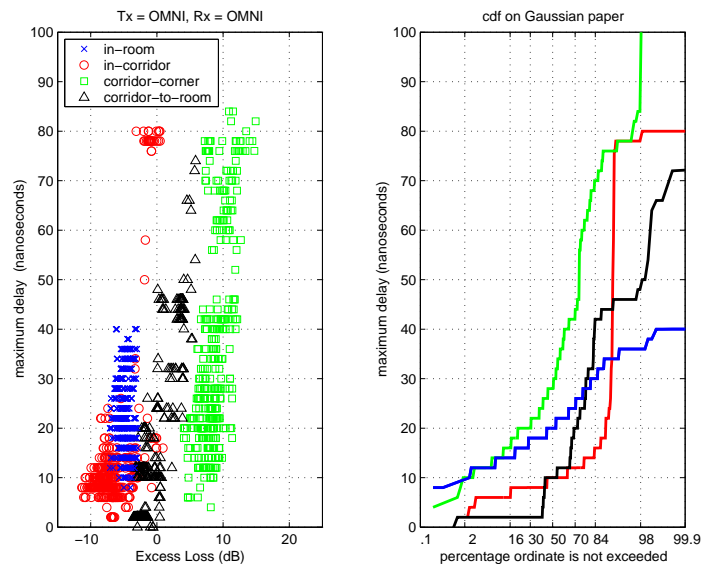


Figure 1. Maximum delay versus excess loss from four canonical indoor scenarios measured with linearly polarized omnidirectional receive and transmit antennas.

Figure 2 statistically demonstrates the different effects of the channels in the frequency domain.

The Institute has developed a geometric optics (or ray-tracing) model for calculating the field strength and impulse response of an indoor radio propagation channel, characterizing an anechoic chamber, and analyzing the coupling mechanisms between rooms. In an attempt to assess the validity of the ray-trace model, we have investigated the accuracy of some of the inherent assumptions. Using the exact Sommerfeld formulation for a source above a dielectric half space, a thorough investigation into the geometric optics (GO) approximation was performed. This study demonstrated discrepancies associated with surface-wave and near-field effects and the use of plane-wave Fresnel reflection coefficients, as is common in ray-trace models. Figure 3 shows fields from an elementary horizontal dipole close to a dielectric surface calculated from the GO approximation (with and without the Norton surface-wave term added) and numerical evaluation of Sommerfeld's formulation. A discernable pseudo-lateral wave phenomenon was identified that produces an interference pattern in the Sommerfeld solution with respect to the GO plus Norton term approximation at relatively high frequencies when the source and observation points are near the surface.

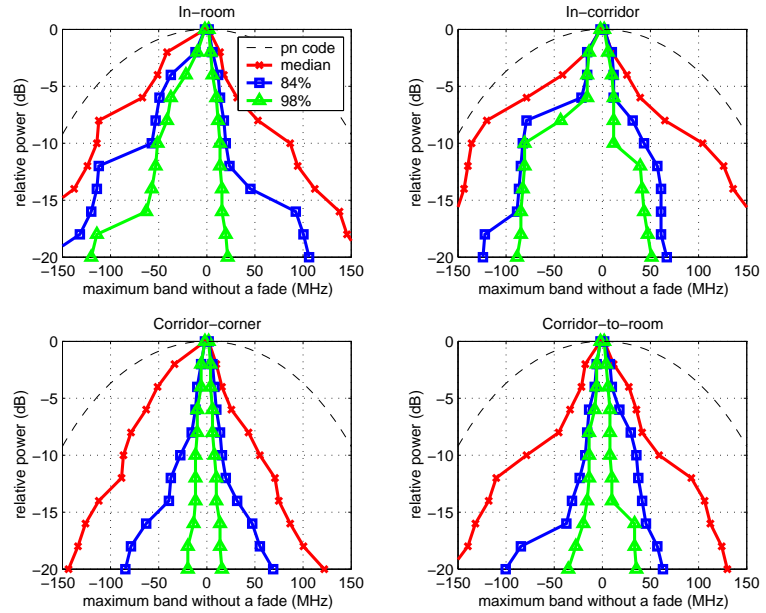


Figure 2. Channel bandwidth statistics from four canonical indoor scenarios measured with linearly polarized omnidirectional receive and directional transmit antennas.

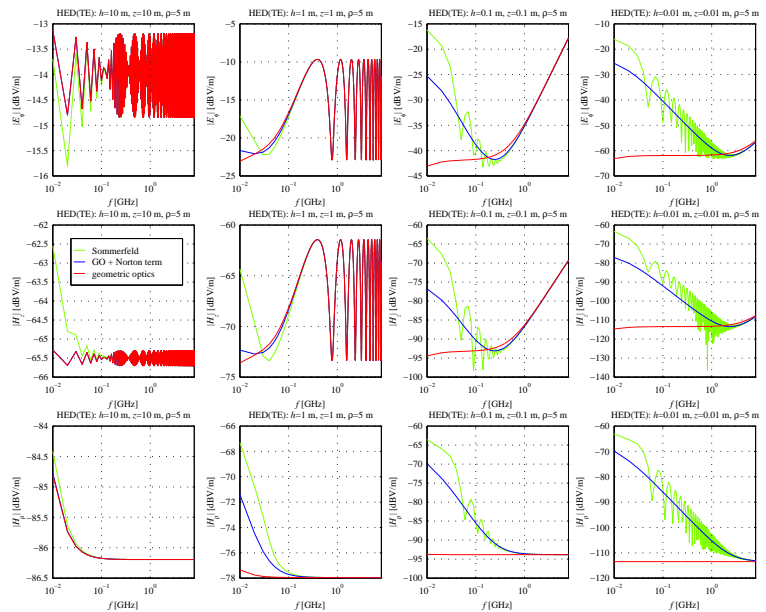


Figure 3. Near-surface effects on field strength of an elementary horizontal electric dipole above a concrete half space.

### Recent Publication

M.G. Cotton, E.F. Kuester, and C.L. Holloway, "An investigation into the geometric optics approximation for indoor propagation models," *Radio Science*, vol. 37, no. 4, pp. 1-1 – 1-22, Jul.-Aug. 2002.

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